(12) UK Patent Application (19) GB (11) 2 342 996 (13) A

(43) Date of A Publication 26.04.2000

(21) Application No 9823059.2

(22) Date of Filing 21.10.1998

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(51) INT CL^7
G01F 23/296, G01S 7/292 13/86 // G01S 7/527

(52) UK CL (Edition R)
G1G GEV
H4D DAA DRPG DSPL D344 D352 D40X D460

(56) Documents Cited
GB 2191055 A GB 2054851 A

(58) Field of Search
UK CL (Edition Q) G1G GEV GPL GRE, H4D DRPK DRPX DSPL
INT CL^6 G01F 23/296, G01S 7/28 7/282 7/292 7/523 7/524 7/527
Online: WPI

(54) Abstract Title
Acoustic pulse-echo ranging system

(57) A method of operating a pulse echo ranging system comprising a transducer assembly (14) for providing transmission and reception of high frequency energy pulses at substantially different plural frequencies. The method uses signals received by the transducer assembly to generate an echo profile for signals received at at least a first of the frequencies and utilises the signal at another of the frequencies to enhance the recovery of data beyond that obtained from the first signal alone. The system is used to monitor the level of sludge in a body of liquid.

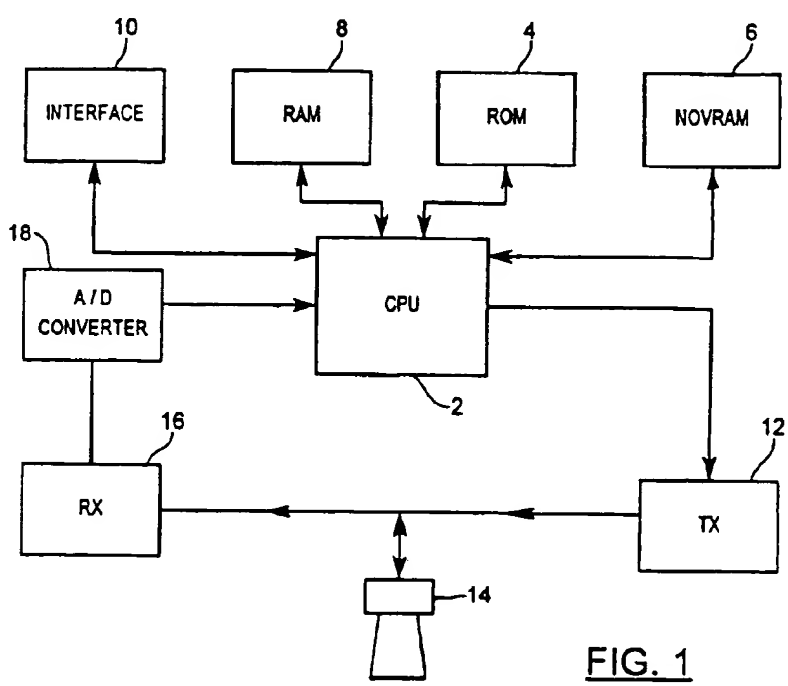

FIG. 1

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At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

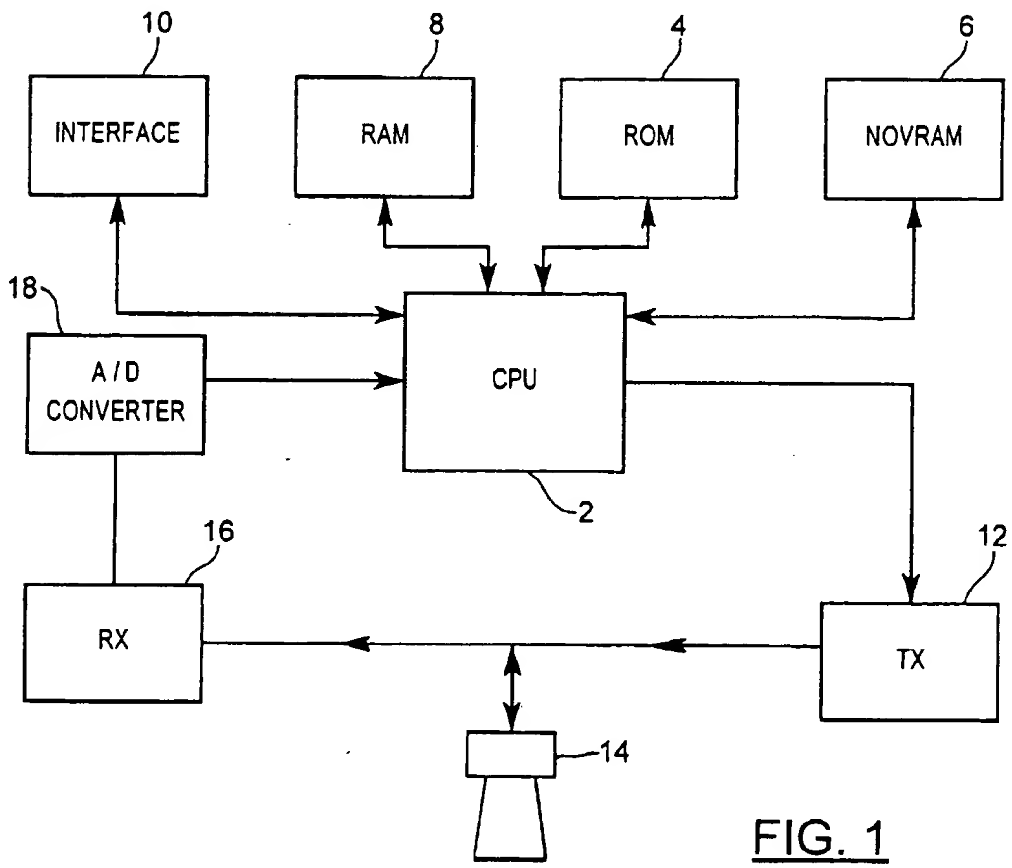

FIG. 1

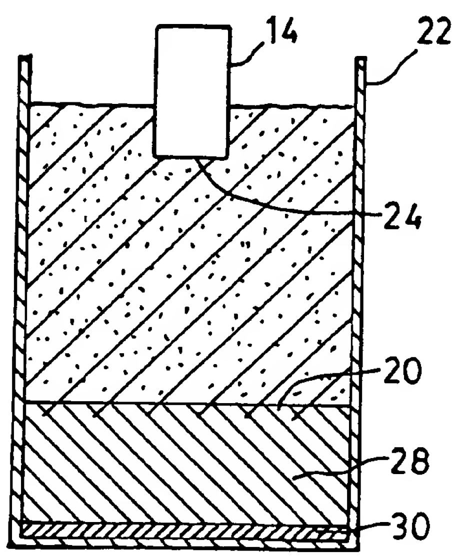

FIG. 2

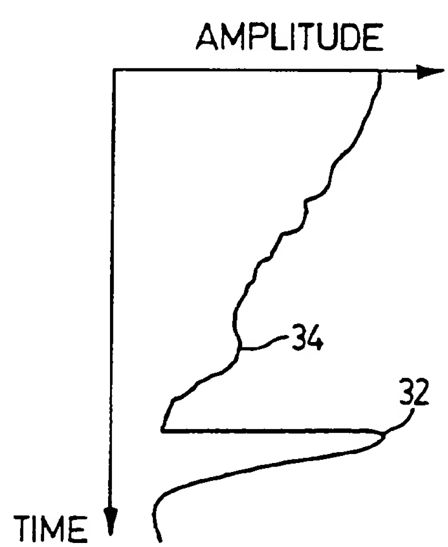

FIG. 3

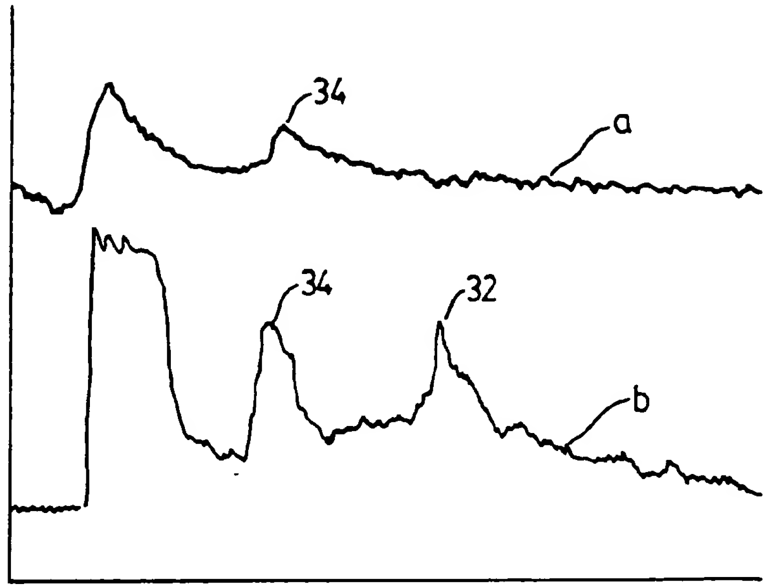

FIG. 4

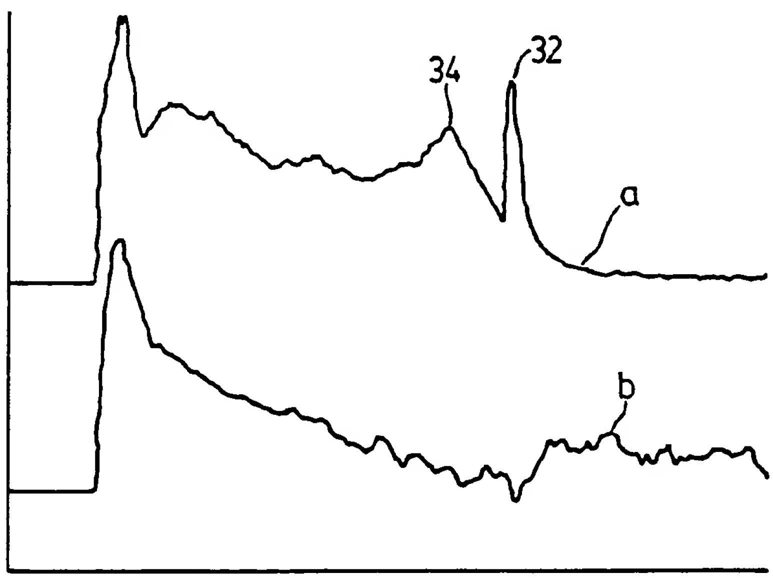

FIG. 5

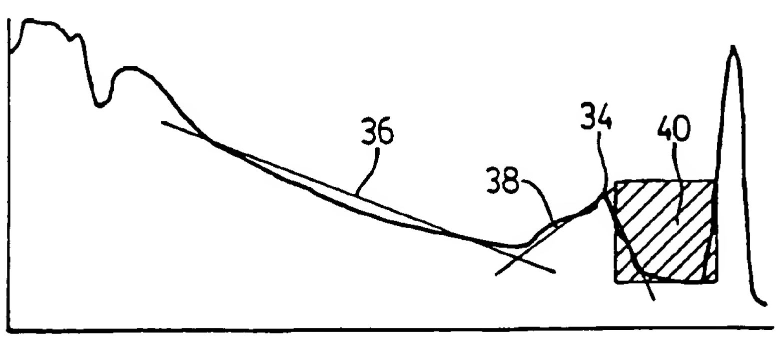

FIG. 6

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ACOUSTIC PULSE ECHO RANGING SYSTEM

This invention relates to pulse echo ranging systems, and more particularly although not exclusively to systems for monitoring the level of sludge in a body of liquid.

In a number of applications, it is necessary to monitor liquids containing significant quantities of suspended materials, which materials may tend to separate or accumulate as a separate phase beneath a body of clearer liquid. A parameter which it is frequently desired to monitor is the level of the interface between settled material or sludge, and a supernatant liquid.

Suspended material in liquids tends to reflect or disperse acoustic energy, although the extent of this effect is frequency dependent. The effectiveness of a pulse echo ranging system in determining the position of an interface between a sludge layer and a supernatant liquid will depend upon the presence of suspended material, including gas bubbles, in the supernatant layer, and the concentration and nature of particles in the sludge layer. It is difficult to select a transducer frequency which will provide reliable detection of the interface under all circumstances.

Since transducers used in such systems will normally operate submerged, there is the possibility of build-up of material passing out of suspension and liquid and building up on the transducer assembly. Such build-up can be inhibited by ultrasonic insonification of vulnerable surfaces, particularly the radiating surface of the transducer assembly, but in practice, the most effective frequencies for operation of the transducer, if it is to be self-cleaning, often fall in a different range from those providing best detection of the sludge/liquid interface.

According to the invention, a method of operating a pulse echo ranging system comprises operating a transducer

assembly to provide transmission and reception of pulses of high frequency energy at plural substantially different frequencies, and signals received by the transducer assembly are to generate an echo profile for signals received at at least a first of the frequencies, and utilizing the signal at another of the frequencies to enhance the recovery of data beyond that obtained from the first signal alone.

This enhancement may be achieved in various ways. Of two frequencies, one may be used to generate an echo profile and the other to clean the radiating surface of the transducer to maintain efficiency. If echo profiles are recovered for two or more frequencies, the additional profiles may be utilized to enhance the reliability of recovery wanted data. For example, if supernatant liquid contains large quantities of suspended material, acoustic energy at a frequency best suited to detecting a sludge interface may be so attenuated before reaching the interface that detection is not practicable. In this case, the lower frequency signal may provide additional penetration in order to detect the sludge interface and thus improve reliability.

Furthermore, if two or more echo profiles are recovered, the profile recovered from a signal which is not heavily reflected by a sludge interface or other interface which it is desired to detect may be utilized as a reference signal against which echoes occurring in the echo profile from a signal at a different frequency may be assessed. Alternatively, the profiles from different frequencies may be summed, or differenced on the basis that the response from an interface to be detected to signals at substantially different frequencies will be substantially different.

If the echo responses at different frequencies are available, it may be possible to deduce characteristics such as quantities of suspended solids, layer density, presence of bubbles, and so on from the different responses to the different frequencies.

These various features may of course be used in combination, according to the manner in which a microcontroller controlling the system is programmed.

Further features of the invention will become apparent from the following description with reference to the accompanying drawings, in which:

Figure 1 is a simplified schematic diagram of a pulse echo ranging system;

Figure 2 is a section through a settling tank illustrating an exemplary operational environment for the mechanism;

Figure 3 is a graph illustrating an exemplary echo profile produced by a signal component at one of the frequencies utilized;

Figure 4 compares echo responses at two different frequencies in a primary clarifier;

Figure 5 compares echo response at the two different frequencies in a secondary clarifier;

Figure 6 is an annotated graph illustrating how echo data may be interpreted to provide additional data.

Referring to Figure 1, there is shown a simplified schematic diagram of a pulse echo ranging system controlled by a central processing unit (CPU) 2. Typically the CPU 2 will be incorporated in a microcontroller implementing peripheral functions used to implement some of the other blocks shown in Figure 1 as well as additional functions not described. The CPU operates under a control program stored in read-only memory (ROM) 4, utilizing parameters stored in non-volatile random access memory (NOVRAM) 6, and provided with working memory in the form of random access memory (RAM) 8. An

interface 10 provides for the export of data from the unit, and the import of operating parameters. Data may be exported in the form of a display, telemetry signals or alarm signals. The CPU 2 also controls a transmitter 12 which controls the timing, frequency and amplitude of high frequency pulses applied to a transducer 14. A receiver 16 receives return echo signals from the same or a different transducer, amplifies them, usually logarithmically, and applies them to an analog to digital converter 18, from where the digital echo profile is stored in RAM 8 for further processing

The operation of such systems is described in more detail in our U.S. Patents Nos. 4,596,144; 4,831,565; 4,890,266; 4,999,998 and 5,076,751, and only features of difference will be discussed further below.

Referring to Figure 2, this shows an exemplary application of the invention, used for monitoring a sludge interface 20 in a tank 22, of the invention, in which the transducer 14 is mounted with at least its radiating face 24 submerged in the liquid content of the tank. Above the interface 20, the liquid content is liquid containing suspended material and possibly gas bubbles, while a denser sludge phase 28 settles out beneath the interface and above the bottom wall 30 of the tank.

Figure 3 illustrates an exemplary echo response to a high frequency acoustic pulse emitted by the transducer 14. In this instance there is a strong echo 32 from the bottom of the tank, while the weaker true echo 34 from the interface 20 shows little increase in amplitude relative to the immediately preceding portion of the profile which consists not only of a component due to ranging of the transducer, but also energy reflected by the suspended material in the liquid above the interface. This reflected energy tends to mask the wanted echo.

These phenomena are illustrated further in Figures 4 and 5, which show how the responses to different pulse frequencies can change in different environments. Graphs a and b in each Figure represent logarithmic plots of the amplitude of the echo profiles produced at 44 kHz and 150 kHz respectively in a tank acting as a primary clarifier and a tank acting as a secondary clarifier. In Figure 4, the lower frequency (trace b) propagates well through liquid containing substantial amounts of suspended material, and clear echoes 32 and 34 can be seen both from the bottom of the tank and the sludge interface. At the higher frequency (trace a), absorption and scattering result in the echo 34 being much less marked, and the echo 32 being wholly absent. By contrast, behaviour in the secondary clarifier is quite different. In this case the suspended material is light and "fluffy". It is penetrated well by the higher frequency (trace a), providing clear echoes 32 and 34 from the bottom of the tank and the sludge interface, whereas the lower frequency is severely attenuated and produces no recognizable echoes.

In a presently preferred embodiment, both frequencies are generated simultaneously by a common acoustic transducer. Piezoelectric transducers used in acoustic ranging systems are commonly capable of resonating in different modes having substantially different resonant frequencies, and the transmitter 12 is configured to generate energy at two such widely spaced frequencies such as to cause the transducer to radiate at both frequencies during a pulse. For best results, the frequencies should have at least 2:1 ratio. Exemplary frequencies are 44 kHz and 150 kHz, or 50 kHz and 120 kHz. It is possible to use more than two frequencies, or to use a transducer assembly containing multiple piezoelectric elements having different frequencies, or to energize the transducer at different frequencies sequentially. It is also possible to utilize a transducer assembly comprising two separate transducers, for example two acoustic transducers operating at different frequencies. In some applications, it may be possible to combine an

acoustic microwave transducer so as to exploit the different penetration and dispersion characteristics of the different types of radiation involved, for example, in applications where it is desired to detect both a foam interface and a liquid interface in a tank with the transducer assembly above both levels.

Regardless of the transmitter and transducer system used, there are various ways of using the invention to provide enhanced performance. At a lowest level, a higher frequency is used to generate an echo response for analysis, and acoustic energy at a lower frequency is used to inhibit deposition of solids on a radiating surface of the transducer assembly thus improving reliability. Preferably however, echo responses are obtained at each frequency and combined in some manner to provide enhanced data.

For example, the echo responses may simply be summed, providing a combined response in which echoes of energy occurring at any of the frequencies will normally be apparent. Even though one frequency fails to provide a substantial echo response from a feature of interest, the second frequency may result in a satisfactory response. An alternative or additional approach is to difference the responses at two frequencies. The resulting combined response will then represent the differences between the reflective behaviour of targets at the two frequencies and may enable distinct echo responses to be detected where the summary approach fails. A frequency which does not provide good echo responses may nonetheless be used as a reference against which to detect peaks or discontinuities in response at another frequency.

Comparing responses at different frequencies may permit further characteristics of liquid in a vessel to be determined, since the response to different types of suspended material at different frequencies is different. Referring to Figure 6, a portion of the echo profile 36

consists of reverberation from suspended particles in the supernatant liquid, a portion 38 preceding the peak 34 from the sludge interface represents enhanced reflection from "fluff" of particle gathering above the interface, while the sharply depressed portion 40 of the response between the peak 34 and the peak 32 representing the reflection from the bottom of the tank represents high absorptive properties of the sludge beneath the interface. It will also be noted that the actual peak 34 due to reflection at the interface is quite small, but the peak is emphasized by the sharply contrasting reflective properties of the layers on either side of the peak. At a higher frequency, the reverberation from the suspended particles will typically be greater, and while the reflection from the interface may produce a more marked peak, this may be masked to a greater extend by reverberation. On the other hand, the reflection and dispersion by the fluff may be substantially less. These differing responses may permit substantial interpretation of systems whose characteristics have been the subject of empirical observation.

CLAIMS

1. A method of operating a pulse echo ranging system comprising a transducer assembly to provide transmission and reception of pulses of high frequency energy at plural substantially different frequencies, using signals received by the transducer assembly to generate an echo profile for signals received at at least a first of the frequencies, and utilizing the signal at another of the frequencies to enhance the recovery of data beyond that obtained from the first signal alone.

2. A method according to claim 1, wherein the high frequency energy is acoustic energy and one frequency is used to generate an echo profile, and a second frequency to insonify a radiating surface of the transducer assembly to render it self cleaning.

3. A method according to claim 1 or 2, wherein the received signals are used to generate an echo profile for signals received at two frequencies, and the profile combines data from the at least two signals.

4. A method according to claim 3, wherein the received signals are summed.

5. A method according to claim 3, wherein the received signals are differenced.

6. A method according to claim 3, wherein a signal received at a second frequency is used as a reference against which the first signal can be compared to detect echoes in the latter.

7. A method substantially as hereinbefore described with reference to the accompanying drawings.

8. A pulse-echo ranging system programmed to perform the method of the invention.

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Application No:	GB 9823059.2	**Examiner:**	Hannah Bryant
Claims searched:	1-8	**Date of search:**	12 January 1999

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.Q): G1G (GPL,GRE,GEV), H4D (DSPL, DRPX, DRPK)

Int Cl (Ed.6): G01F 23/296, G01S 7/28, 7/282, 7/292, 7/523, 7/524, 7/527

Other: Online: WPI

Documents considered to be relevant:

Category	Identity of document and relevant passage	Relevant to claims
X	GB2191055 (FURUNO) see whole document	1
X	GB2054851 (FRIED) see whole document	1

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
		E	Patent document published on or after, but with priority date earlier than, the filing date of this application.
&	Member of the same patent family		